Vapor Intrusion Screening Levels for Workers

APPLICABILITY: This memo is focused on developing risk-based indoor air levels for **adult commercial workers** in buildings that are not used for residential purposes. If the property meets the definition of industrial land use (i.e., qualifies for Method C in the Model Toxics Control Act (MTCA) Cleanup Rule[1]), potentially liable persons (PLPs) will be asked to work with the Washington State Department of Ecology (Ecology) to develop appropriate VI screening levels.

I. Introduction

Default vapor intrusion (VI) risk-based indoor air levels for workers are provided in Ecology's Cleanup Levels and Risk Calculations (CLARC) database.[2] These default VI levels apply at sites where **adults who are working** inside commercial buildings are (or potentially are) the receptors who represent reasonable maximum exposure (RME) to indoor air contamination caused by vapor intrusion. CLARC also provides soil gas and groundwater screening levels that are protective of indoor air for adult workers.

CLARC's risk-based indoor air levels for adult workers are not Method B or C air cleanup levels (CULs), and neither are CLARC's soil gas and groundwater VI screening levels. Rather, these levels are health-protective indoor air, soil gas, and groundwater concentrations. These concentrations may be used during VI assessments when:

- The current building being assessed is not being used as a residence –and–
- Adult workers are currently the primary indoor receptors of concern –and–
- The assessment is focused on the question of whether VI impacts are or could potentially result in unacceptable indoor air contaminant levels within the building.

II. Why are VI risk-based indoor air levels for workers needed?

VI risk-based indoor air levels for workers supplement the VI levels already in CLARC.

CLARC contains Method B and C air cleanup levels. It also includes soil gas and groundwater VI screening levels that are back-calculated from those cleanup levels. Individual Method B air cleanup levels and their corresponding soil gas and groundwater VI screening levels are based on a target cancer risk and hazard quotient (HQ) of 1 x 10^{-6} (i.e., one in one million excess lifetime cancer risk) and 1.0, respectively. Those cleanup and screening levels assume that the receptor will be exposed continuously – all day and every day throughout the year. Indoor workers are routinely exposed much less frequently than that. Moreover, Method B air cleanup levels are protective for children as well as adults and in most workplaces, children are not the primary receptors of concern.

Individual Method C industrial air cleanup levels, and their corresponding soil gas and groundwater VI screening levels, are only intended to be protective of adults. However, like the Method B levels, they

[1] https://apps.leg.wa.gov/WAC/default.aspx?cite=173-340 (MTCA Cleanup Rule)
[2] https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Contamination-clean-up-tools/CLARC

assume that receptors will be exposed continuously (i.e., 24 hours/day; 365 days/year). In addition, they are based on a target cancer risk of 1 x 10^{-5} (i.e., one in one hundred thousand excess lifetime cancer risk), which is not sufficiently conservative for VI screening. A target cancer risk of 1 x 10^{-6} should be used for screening to be protective of the cumulative cancer risk goal for multiple chemicals (i.e., the total cancer risk shall not exceed 1 x 10^{-5}).

III. How are VI risk-based indoor air levels for workers calculated?

Air cleanup levels in the MTCA Cleanup Rule are calculated by using the equations in WAC 173-340-750 (Equations 750-1 and 750-2).[3] Pre-calculated air cleanup levels based on adult exposure (using Method C adult inputs) are available in CLARC for many volatile substances, and these can be adjusted to obtain indoor air VI risk-based levels for adult workers at commercial sites, as described below.[4]

Carcinogens

For carcinogens, the Method C air CULs are adjusted by reducing both the target (acceptable) cancer risk (from 1 x 10^{-5} to 1 x 10^{-6}) and the assumed degree of exposure. A conservative default RME indoor air exposure pathway scenario for a worker may assume exposure at the workplace for 9 hours/day, 5 days/week, 50 weeks/year, for 25 years. This equates to an exposure frequency (EF) of 250 days/year and an exposure duration (ED) of 25 years, both of which are upper-bound exposure factors used in EPA Superfund human health risk assessments (EPA, 2014)[5] to evaluate worker exposure. Based on these assumptions, the EF term is reduced from 1 (the Method C default value) to (9 hr/d x 250 d/y x 25 y) ÷ (24 hr/d x 365 d/y x 30 y), or 0.214 (*see* the changes to MTCA Equation 750-2 shown in **Attachment 1)**. This has the effect of **increasing** the risk-based level about 4.67 times – compared to the carcinogenic Method C cleanup level.

To adjust the acceptable risk for commercial workers from 1 x 10^{-5} to 1 x 10^{-6}, the risk-based level for workers derived above is then reduced by 10 times. The combination of these two changes results in the following simplified equation (for cancer endpoints):

$$\text{Worker}_{\text{RBL}} = \text{Method C}_{\text{CUL}} \times 0.467$$

(RBL = Risk-Based Level; CUL = Cleanup Level)

[3] https://apps.leg.wa.gov/wac/default.aspx?cite=173-340-750 (Cleanup standards to protect air quality.)

[4] Although the simplified equations provided in this guidance result in approximate worker risk-based levels, the risk-based levels proposed to be included in CLARC will be fully calculated (*see* **Attachment 1**), and then rounded to 2 significant figures. The calculation of VI screening levels for groundwater and soil gas will use the unrounded worker air risk-based level. VI worker risk-based levels should be calculated consistent with the methods in CLARC if PLPs want to use alternate exposure assumptions on a site-specific basis.

[5] EPA. (2014). Human health evaluation manual, supplemental guidance: Update of standard default exposure factors. OSWER Directive 9200.1-120. https://nepis.epa.gov/Exe/ZyNET.exe/9100UGU2.TXT?ZyActionD=ZyDocument&Client=EPA&Index=1991+Thru+1994&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A%5Czyfiles%5CIndex%20Data%5C91thru94%5CTxt%5C00000026%5C9100UGU2.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=hpfr&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=1&SeekPage=x&ZyPURL

Noncarcinogens

A similar approach is applied for noncarcinogens. The EF term is reduced from 1 (the Method C default value) to (9 hr/d x 250 d/y) ÷ (24 hr/d x 365 d/y), or 0.257.[6] This has the effect of increasing the risk-based level about 3.89 times – compared to the Method C cleanup level for noncancer effects. No further adjustment to the screening level for workers is needed since the Method C target HQ is 1. The simplified adjustment equation (for noncancer endpoints) is therefore:

$$\text{Worker}_{\text{RBL}} = \text{Method C}_{\text{CUL}} \times 3.89$$

Example Calculation

The indoor air VI risk-based levels for workers resulting from the adjustments above are associated with a target cancer risk of 1 x 10^{-6} and a target HQ of 1.0. An example calculation for tetrachloroethylene (PCE) is provided in the tables below.

Table 1: Air **Cancer** Endpoint (µg/m^3)

Chemical	Method B_{CUL} (1E-06)	Method C_{CUL} (1E-05)	$Worker_{RBL}$ (1E-06)
PCE	9.6	96	45

Table 2: Air **Noncancer** Endpoint (µg/m^3)

Chemical	Method B_{CUL} HQ 1	Method C_{CUL} HQ 1	$Worker_{RBL}$ HQ 1
PCE	18	40	160

Notes:

The values in the table above are rounded to 2 significant figures.

CUL = Cleanup Level
HQ = Hazard Quotient
RBL = Risk-Based Level
1E-06, 1E-05 = Cancer risk levels
Worker = Adult worker exposure via inhalation of volatiles in indoor air within a building (not used as a residence).

[6] Since the averaging time (AT) for noncancer effects is equal to the ED x 365 d/y, the ED in the denominator is cancelled out and is not needed for determining the EF term.

IV. Summary and Example Scenarios

Indoor air risk-based levels for workers, and the associated soil gas and groundwater VI screening levels, will always be higher than CLARC's Method B air cleanup and VI screening levels, and Method C noncarcinogenic air cleanup and VI screening levels. Soil gas and groundwater VI screening levels for assessing buildings where indoor adult workers are the receptors of greatest potential concern (i.e., represents RME) are based on the indoor air VI risk-based levels for workers. Consequently, they will be about: a) 0.467 times lower than their corresponding carcinogenic Method C screening levels, and b) 3.89 times higher than their corresponding noncarcinogenic Method C screening levels.

Example Scenarios at Commercial Sites (i.e., not industrial)

Scenario #1: Near-source soil gas or shallow groundwater concentrations in the vicinity of a commercial building exceed Method B VI screening levels (SLs). They also exceed soil gas and groundwater VI risk-based levels for workers. Indoor air sampling should typically be performed.

Scenario #2: Near-source soil gas or shallow groundwater concentrations in the vicinity of a commercial building exceed Method B soil gas and groundwater VI SLs. However, they are below soil gas and groundwater VI SLs for workers. Indoor air sampling may therefore not be needed. VI is a potential future concern if building use changes.

Scenario #3: VI-caused indoor air concentrations within a commercial building exceed Method B air cleanup levels. They also exceed indoor air VI risk-based levels for workers. VI mitigation should be performed.

Scenario #4: VI-caused indoor air concentrations within a commercial building exceed Method B air cleanup levels. However, they are below indoor air VI risk-based levels for workers. VI mitigation may not be needed.

ATTACHMENT 1
MTCA DEFAULT AND WORKER AIR EQUATIONS

MTCA AIR CLEANUP LEVEL EQUATION 750-1 – NONCARCINOGENIC EFFECTS

Default Method C Equation (based on an adult)

$$Air\ CUL_{nc}\left(\frac{\mu g}{m^3}\right) = \frac{RfD_i\left(\frac{mg}{kg-d}\right) \times ABW\ (70\ kg) \times UCF\left(1{,}000\frac{\mu g}{mg}\right) \times HQ\ (1) \times AT\left(6\ y \times 365\frac{d}{y}\right)}{BR\left(20\frac{m^3}{d}\right) \times ABS\ (1) \times ED\ (6\ y) \times EF\left(365\frac{d}{y}\right)}$$

Note:

AT, which is the Averaging Time, is a key component to the cleanup level equation. AT is the period over which exposure is averaged. It is normally expressed in days. For noncancer effects, exposure is averaged over the period of exposure, which is 6 years x 365 days/year (d/y). The MTCA default equation assumes an exposure frequency (EF) of 365 d/y, which is cancelled out (indicated by the slash mark) and can be expressed as 1 if the AT is only expressed in years.

Worker Modified Equation

$$Air\ CUL_{nc}\left(\frac{\mu g}{m^3}\right) = \frac{RfD_i\left(\frac{mg}{kg-d}\right) \times ABW\ (70\ kg) \times UCF\left(1{,}000\frac{\mu g}{mg}\right) \times HQ\ (1) \times AT\left(25\ y \times 365\frac{d}{y} \times 24\ \frac{h}{d}\right)}{BR\left(20\frac{m^3}{d}\right) \times ABS\ (1) \times ED\ (25\ y) \times EF\left(250\frac{d}{y}\right) \times ET\left(9\frac{h}{d}\right)}$$

Note:

AT in the worker noncancer equation above is expressed as the total exposure period in hours rather than days. Since the AT for noncancer effects is equal to the ED x 365 d/y x 24 hours/day (h/d), the ED in the denominator gets cancelled out (indicated by the slash mark) and is not needed for determining the EF term. Under the worker equation, the **EF factor** is calculated as: worker period of exposure (hours/year) ÷ Method C default period of exposure (hours/year), or (9 h/d x 250 d/y) ÷ (24 h/d x 365 d/y) = 0.257.

CLARC Note:

The EF factor in the Worker Modified Equation note could be used in the default equation (instead of 1) to yield an indoor air screening level for workers protective of noncancer effects. However, indoor air screening levels for workers in CLARC will be calculated using the full equation above. The unrounded worker air screening level will be used to estimate groundwater and soil gas screening level concentrations protective of indoor air, which will then be rounded to 2 significant figures. Due to errors that occur when rounding, Ecology does not recommend using the simplified equations found on pages 2 and 3 of this guidance. VI worker screening levels should be calculated consistent with the methods in CLARC if PLPs want to use alternate exposure assumptions on a site-specific basis.

Definitions

ABS = Inhalation absorption fraction (1.0) (unitless)
ABW = Average Body Weight (kg)
Air CULnc = Noncancer air cleanup level (µg/m^3)
AT = Averaging Time (period of exposure in days or hours)
BR = Breathing Rate (m^3/day)
ED = Exposure duration (years)
EF = Exposure frequency (days/year or as an EF factor)
ET = Exposure time (hours/day)
HQ = Target noncancer hazard quotient (1) (unitless)
RfDi = Inhalation Reference Dose (mg/kg-day)
UCF = Unit Conversion Factor (µg/mg)

MTCA AIR CLEANUP LEVEL EQUATION 750-2 – CARCINOGENIC EFFECTS

Default Method C Equation (based on an adult)

$$Air\ CUL_c\left(\frac{\mu g}{m^3}\right) = \frac{RISK(1\times10^{-5})\times ABW(70\ kg)\times UCF\left(1{,}000\frac{\mu g}{mg}\right)\times AT\left(75\ y\times 365\frac{d}{y}\right)}{CPF_i\left(\frac{kg-d}{mg}\right)\times BR\left(20\frac{m^3}{d}\right)\times ABS\ (1)\times ED\ (30\ y)\times EF\left(365\frac{d}{y}\right)}$$

Note:

AT, which is the Averaging Time, is a key component to the cleanup level equation. AT is the period over which exposure is averaged. It is normally expressed in days. For cancer effects, exposure is averaged over a lifetime, which would be 75 years x 365 d/y. The MTCA default equation assumes an exposure frequency (EF) of 365 d/y, which is cancelled out (indicated by the slash mark) and can be expressed as 1 if the AT is only expressed in years.

Worker Modified Equation

$$Air\ CUL_c\left(\frac{\mu g}{m^3}\right) = \frac{RISK\ (1\times10^{-6})\times ABW\ (70\ kg)\times UCF\left(1{,}000\frac{\mu g}{mg}\right)\times AT\left(75\ y\times 365\frac{d}{y}\times 24\ \frac{h}{d}\right)}{CPF_i\left(\frac{kg-d}{mg}\right)\times BR\left(20\frac{m^3}{d}\right)\times ABS\ (1)\times ED\ (25\ y)\times EF\left(250\frac{d}{y}\right)\times ET\left(9\frac{h}{d}\right)}$$

Note:

AT in the worker cancer equation above is expressed as a total lifetime in hours rather than days. Under the worker equation, the **EF factor** is calculated as: worker period of exposure (hours) ÷ Method C default period of exposure (hours), or (9 h/d x 250 d/y x 25 y) ÷ (24 h/d x 365 d/y x 30 y) = 0.214.

CLARC Note:

See CLARC note on page 6.

Definitions

ABS = Inhalation absorption fraction (1.0) (unitless)
ABW = Average Body Weight (kg)
Air CULc = Cancer air cleanup level (µg/m^3)
AT = Averaging Time (lifetime in days or hours)
BR = Breathing Rate (m^3/day)
CPFi = Inhalation Carcinogenic Potency Factor (kg-day/mg)
ED = Exposure duration (years)
EF = Exposure frequency (days/year or as an EF factor)
ET = Exposure time (hours/day)
RISK = Acceptable Cancer Risk Level (1 x 10^{-6} for workers)
UCF = Unit Conversion Factor (µg/mg)